N73-11395
CR-128604

THE PERKIN-ELMER CORPORATION
AEROSPACE DIVISION
2855 Metropolitan Place Pomona, California 91767

# FINAL REPORT

# ATMOSPHERIC CONTAMINANT SENSOR

## BOOK 3 OF 3 - ADDENDUM

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NAS 9-12066

Perkin-Elmer SPO No. 30249

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Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Manned Spacecraft Center
R&D Procurement Branch
Houston, Texas

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# ADDENDUM

## INTRODUCTION

Under the terms of Contract NAS9-12066, Appendix 15, the Perkin-Elmer Corporation, Aerospace Division modified the Atmospheric Contaminant Sensor (ACS) to include carbon monoxide measurement.

The period of performance and cost were minimized by utilizing, as much as possible, a Nondispersion Infrared (NDIR) carbon dioxide detector which was recently developed by Arkon Scientific Lab (now Andros Scientific Lab) at Berkeley, California for the NASA Skylab program. A detailed description of the technical operation of the carbon monoxide analyzer was presented at the American Institute of Aeronautics and Astronautics Joint Conference, on Sensing of Environmental Pollutants, from 8 to 10 November 1971 (Attachment 1).

A detailed description of the resultant CO Monitor is included in the operation and maintenance manual, which was provided with Volumes 1 and 2, and will not be repeated here.

## MODIFICATION PROGRAM

The program consisted of, first, converting the recently developed prototype NASA Skylab Carbon Monoxide Analyzer into a prototype Atmospheric Carbon Monoxide Monitor and, second, integrating and testing this device as a black box with the existing ACS. The ACS, with the Carbon Monoxide Monitor integrated, is shown in Figure 15 and the Carbon Monoxide Monitor is shown in Figure 16.

As a result of the reconfiguration process, all unnecessarily qualified or high-reliability components and procedures utilized in the Skylab design were deleted and MIL SPEC substitution made in order to provide a reliable, inexpensive addition to the ACS within the program time schedule.

The schematic diagrams, as generated by Arkon Scientific Labs and delivered to Perkin-Elmer were reviewed. A detailed investigation of the phase-locked loop revealed an ambiguity in the eight phase counter. There were two possible start up modes, only one of which resulted in correct operation. A minor circuit modification was incorporated to prevent the unwanted mode from occurring.

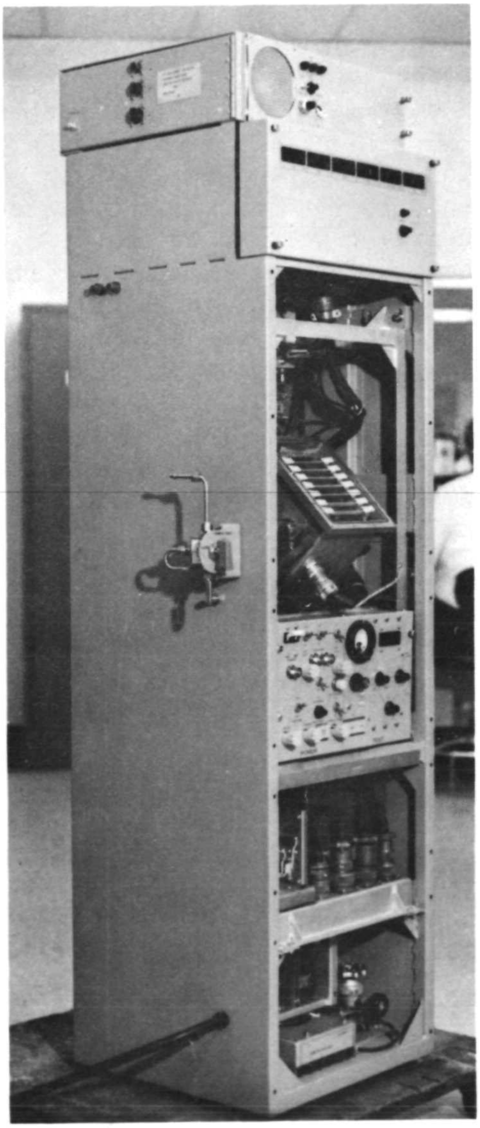


FIGURE 15. ACS with Carbon Monoxide Monitor Integrated

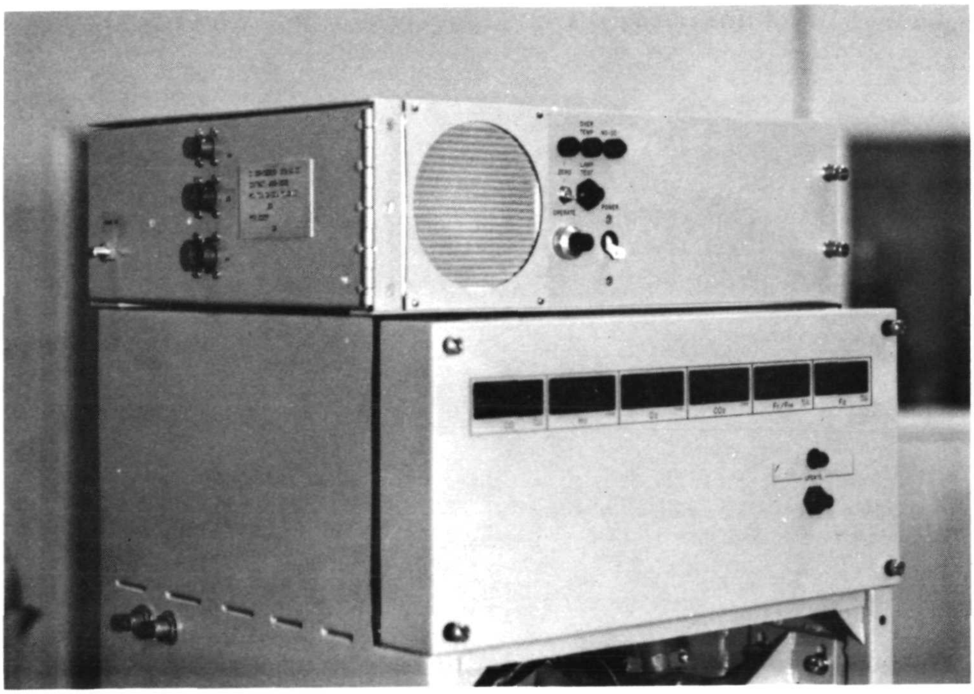


FIGURE 16. Carbon Monoxide Sensor and Readout Panel

## ADDENDUM

The Arkon design included three separate discrete FET input operational amplifiers. Since a hybrid operational amplifier, which exceeds the specifications for the discrete unit, is commercially available and in the interest of cost, size and reliability, Perkin-Elmer decided to replace the discrete operational amplifier with the hybrid in two of the three applications.

A worst case stress analysis of all components was conducted and several components in the power supply were stressed beyond Perkin-Elmer derating rules. The power requirements were reviewed with Arkon personnel and a redesign of the power supply was conducted which resulted in a supply that occupied less volume and met all Perkin-Elmer derating rules.

Stress analysis of the other circuits indicated that only one or two components were overstressed. These components were respecified to meet the circuit requirements.

The two signals that interface between the Carbon Monoxide Monitor and the ACS are the carbon monoxide concentration signal and the pressure transducer signal. A differential line driver and differential line receiver, respectively, are used to isolate the ground commons between the two instruments to prevent any alternating current voltages from appearing on the signal common lines.

The power supplies were bench tested at Perkin-Elmer before delivery to Arkon for integration with the electronics. The printed wiring boards were shipped direct to Arkon for testing.

Engineering support was provided by Perkin-Elmer at Arkon on two occasions to assist in initial system integration and review of documentation and manual preparation.

## DESIGN GOALS AND TEST RESULTS

Table 17 outlines the design goal carbon monoxide analyzer specifications. As design goals, all the specifications were met with the exception of the sample flow rate. The sample flow rate was specified as 0.04 standard cubic feet per hour because this is the flow rate of the ACS system. At this low flow rate, the carbon monoxide analyzer response time would have been extremely long (approximately ten minutes). As a solution, the plumbing arrangement shown in Figure 17 was used to maintain a flow rate through the ACS of 0.04 standard cubic feet per hour and a flow rate of 2.0 standard cubic feet per hour was obtained through the carbon monoxide analyzer which produced a response of less than one minute.

ADDENDUM

TABLE 17

Carbon Monoxide Analyzer Specifications

| Item No. | Conditions | Specifications |
|---|---|---|
| 1 | Type | Fluorescent Source NDIR Carbon Monoxide Analyzer |
| 2 | Monitoring | Continuous duty |
| 3 | Nominal | 760 torr air at 60% R.H. |
| 4 | Input Voltage | 115 volt $\pm$10% single phase ac, 60 $\pm$5% Hz |
| 5 | Output Connector | CO concentration signal of 0 to 10 V dc, 250 Ω max impedance, digital voltmeter display<br>Cabling to the ACS display control panel<br>Zero calibration (relay-operated zero tube)<br>Zero adjusting potentiometer<br>Electronic span calibration |
| 6 | Size and Configuration | 17 x 15 x 5-1/4 in |
| 7 | Constituents | Carbon Monoxide |
| 8 | Range | 0 to 0.1 mmHg (132 ppm at 760 torr) CO |
| 9 | Detectable Limit | 5% of full scale |
| 10 | Accuracy | $\pm$5% of full scale over the full range due to all errors including zero and span drift, temperature, interferences, peak to peak noise, all environments, etc. |
| 11 | Pressure | 20 to 40 inHg |
| 12 | Temperature | 50 to 115°F |

ADDENDUM

TABLE 17 (Cont)

| Item No. | Conditions | Specifications |
|---|---|---|
| 12 | <u>Atmospheric Contamination</u> | |
| | $N_2O$ | 0 to 100 ppm |
| | Oxygen | 15 to 25% |
| | Hydrogen | 0 to 2% |
| | Carbon Dioxide | 0 to 3% |
| | Freon 11 | 0 to 1500 ppm |
| | Freon 12 | 0 to 1500 ppm |
| | Freon 114 | 0 to 1500 ppm |
| | Total Hydrocarbons (w/o $CH_4$) | 0 to 1% |
| | $CH_4$ | 0 to 300 ppm |
| | $H_2O$ | 0 to 3% |
| 13 | Sample Flow Rate | 0.04 scfh |
| 14 | Time Response | Instrumental limited: 10 s; sample flow rate limited: 6 min. To minimize time response, a separate sample transport pump will be provided with each monitor. |
| 15 | Warm-up Time | 1 hour |
| 16 | Linearity | The output characteristics of the device versus CO input shall be linear within $\pm$10% of reading. This allowed variation is from a best fit straight line which passes through the zero-zero coordinate point. This measurement can be taken immediately after zeroing the device. |

TABLE 17 (Concluded)

| Item No. | Conditions | Specifications |
|---|---|---|
| 17 | Weight | 30 lbs |
| 18 | Power | 200 W |
| 19 | Reliability | System operating life shall be 50,000 hours, no limitation on cycles. Major overhaul shall not be required in less than 6000 hours. |
| 20 | Mounting | There must be provisions for securely mounting the instrument on its bottom surface. |
| 21 | Orientation | The device must be capable of operation while at an inclined angle of up to 30° from vertical in any direction. |
| 22 | Calibration | In order to remain within the accuracy specification, the device shall not require zero or span calibration or adjustment more than once each 24 hours. Both calibrations will be remote electronics and require less than one minute. |
| 23 | Maintenance | The device shall not require any kind of maintenance for a period of 2000 hours and must be of a minor nature so that operation is not interrupted for more than 8 hours. |
| 24 | Accessibility | Accessibility shall be provided in order to accomplish calibration and maintenance as noted above. |

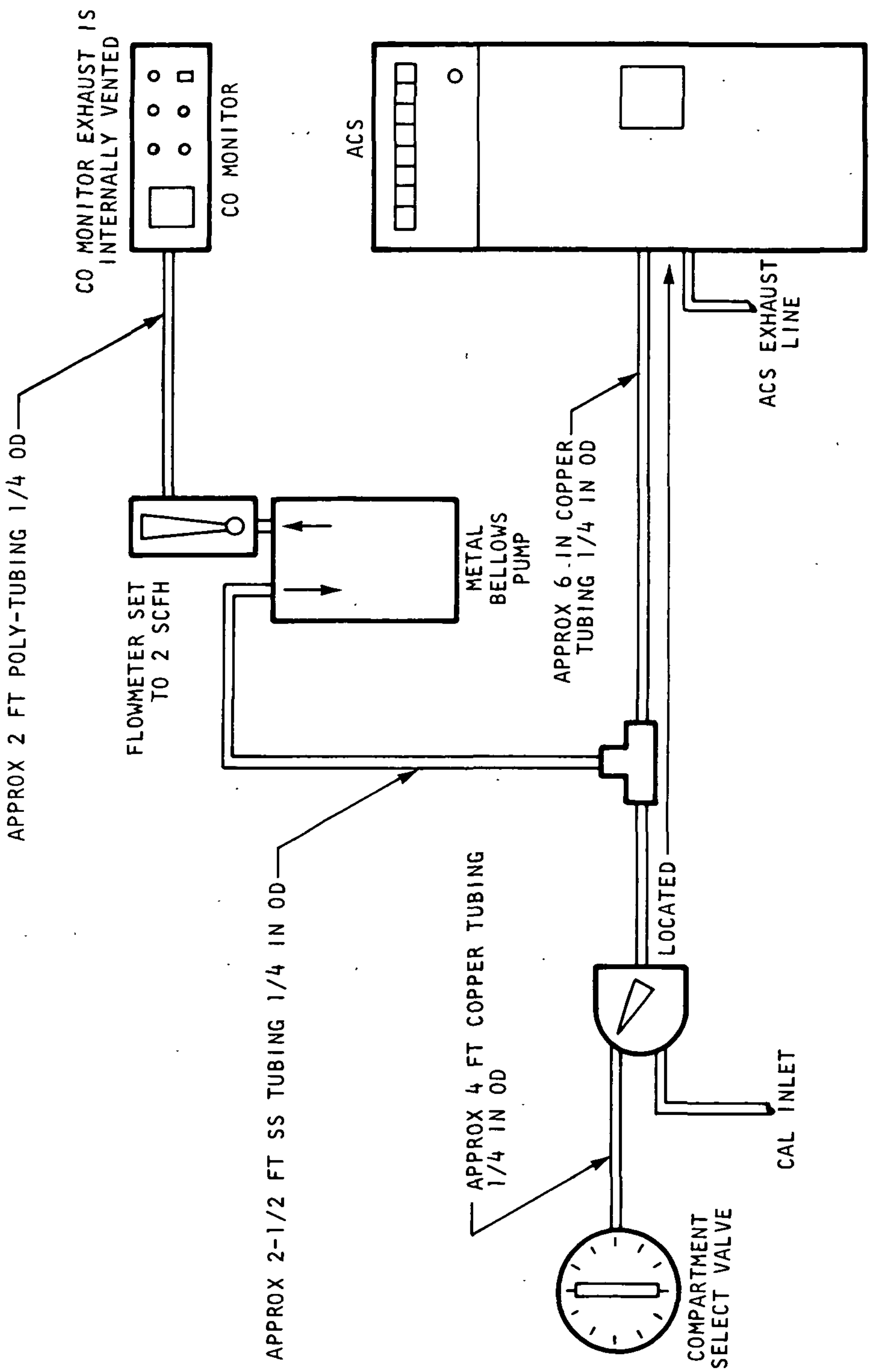



FIGURE 17. Final Plumbing Arrangement

## ADDENDUM

The acceptance Test Data (Attachment 2) provides the detailed test results on each carbon monoxide analyzer. The span check of the analyzers with various test gases indicates that the analyzers do not meet the plus or minus five percent ($\pm 5\%$) full scale accuracy specification. This data requires interpretation before drawing any conclusions relative to the accuracy of the analyzers.

The test gases used in the ATP span checks are listed below, with all relevant data applicable to their Reported* and True** carbon monoxide composition.

| Mixture No. | Vendor | Reported* CO Composition | Corrected True** CO Composition |
|---|---|---|---|
| 71584 | PGP | 82 ppm | 70.9 ppm |
| 9401 | PGP | 97 ppm | 122.0 ppm |
| 9377 | PGP | 68 ppm | 90.1 ppm |
| 9406 | PGP | 9.4 ppm | 12.7 ppm |
| A6416 | Scott | 103 ppm | 103.0 ppm |

The true composition is based upon a series of cross checks between multiple analyzers and multi-gas mixtures, Vendors and concentration levels were performed by Arkon Scientific Laboratory.

When the ATP data is reduced and using the True CO concentration levels, Table 18, the CO analyzer accuracy is within plus or minus five percent ($\pm 5\%$) of full scale, except for one midscale point on S/N 01 which can be attributed to reading error.

## CONCLUSIONS

In conclusion, the carbon monoxide analyzer performs as specified under controlled, measured laboratory environments. The two carbon monoxide analyzers have been placed aboard nuclear submarines (USS Hawkbill, and USS Pintado) for true operational tests. The results of these tests are not available for this report.

TABLE 18. Corrected Acceptance Test Procedure Data

S/N 01

| Mixture No. | Reported CO Concentration | True CO Concentration | Applied Pressure | Calculated True Partial Pressure CO | CO Analyzer Output | Δ Error |
|---|---|---|---|---|---|---|
| 9401 | 97.0 ppm | 122.0 ppm | 733T | 89.4 mT | 85.2 mT (*85.8 mT) | -4.2 mT *(-3.6 mT) |
| 9377 | 68.0 ppm | 90.1 ppm | 733T | 66.0 mT | 60.0 mT (*62.3 mT) | -6.0 mT *(-3.7 mT) |
| 9406 | 9.4 ppm | 12.7 ppm | 734T | 9.3 mT | 7.3 mT (* 9.3 mT) | ( 2.0 mT) *( 0 mT) |
| | | | | *(SPARE CIRCUIT BOARDS) | | |
| S/N 02 | | | | | | |
| 9401 | 97.0 ppm | 122.0 ppm | 740T | 90.3 mT | 93.1 mT | (+2.8 mT) |
| 9377 | 68.0 ppm | 90.1 ppm | 740T | 66.7 mT | 67.7 mT | (+1.0 mT) |
| 9406 | 9.4 ppm | 12.7 ppm | 740T | 9.4 mT | 12.3 mT | (+2.9 mT) |

ADDENDUM/ATTACHMENT 1

# A FLUORESCENT SOURCE NDIR CARBON MONOXIDE ANALYZER

ADDENDUM/ATTACHMENT 1

# A FLUORESCENT SOURCE NDIR CARBON MONOXIDE ANALYZER

W.T. Link, E.A. McClatchie, D.A. Watson, and A.B. Compher

## ABSTRACT

This paper describes a new technique for measuring trace quantities of carbon monoxide by the nondispersive infrared (NDIR) methods. The technique uses the property of infrared fluorescence in a gas to generate a specific source of radiation which is an exact match of the absorption spectrum of the fundamental band of carbon monoxide. This results in an instrument with high sensitivity and specificity for CO. A novel method of referencing using an isotopic species of CO confers great stability on the instrument.

## BASIC OPERATION OF NDIR ANALYZERS

NDIR gas analyzers may be classified by type of infrared source and detector. The simplest form of analyzer is schematically shown in Figure 18.

The simple analyzer suggested by Figure 18 has many shortcomings. The most serious is the interference of other gases, specifically $CO_2$ and $H_2O$ at CO concentrations below 1000 ppm. The main problem is that the filtered source of infrared radiation must have a bandwidth about equal to that of the CO absorption band, and other gases which may have absorption lines intermingled with the CO absorption lines are detected and mistakenly identified as CO.

A very widely used, and generally more sensitive form of NDIR CO analyzer is schematically shown in Figure 19.

This form of analyzer suffers from the fact that the detector is extremely subject to interference by vibration and shock, and at CO concentrations below 50 ppm, the problem of $H_2O$ and $CO_2$ interference becomes acute. Division of the infrared beam into two cells, a sample cell and a standard cell, contributes heavily to the instabilities caused by window dirt and source and detector drift.

## THE ARKON SCIENTIFIC LABS FLUORESCENT NDIR ANALYZER

The fluorescent NDIR analyzer developed by Arkon Scientific Labs to overcome the deficiencies described above is schematically shown in Figure 20.

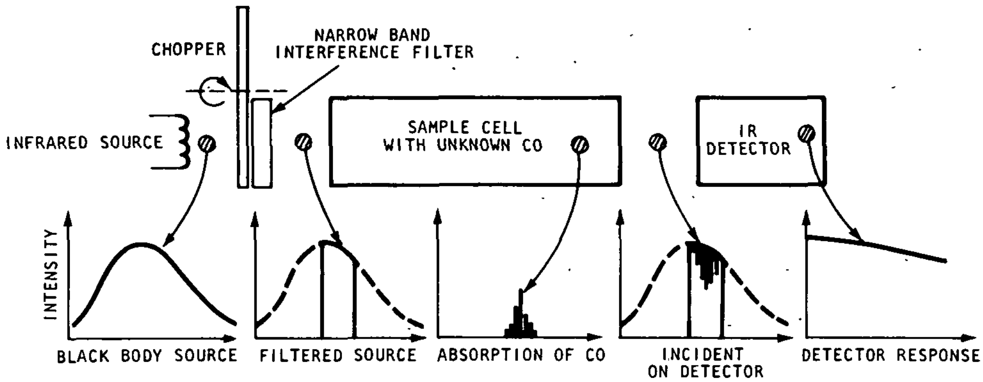



FIGURE 18. The Simplest NDIR Analyzer. The interference filter defines a fairly narrow band of radiation located at the absorption band of CO. The detector is sensitive to all wavelengths.

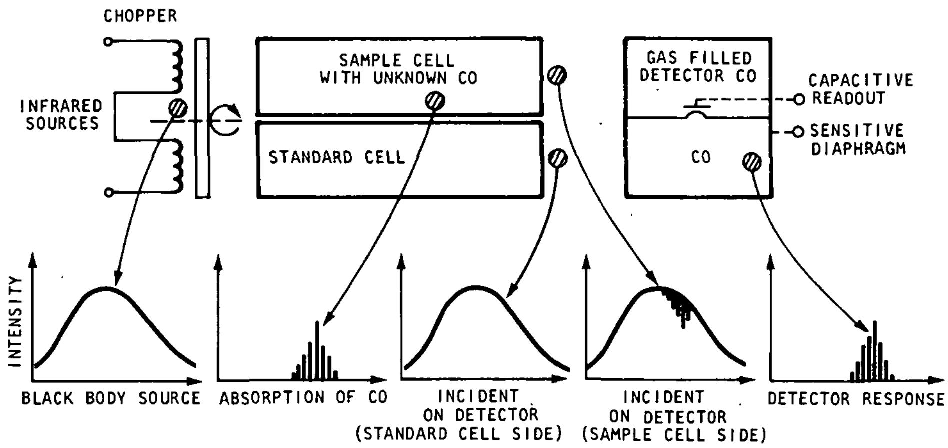



FIGURE 19. Typical NDIR CO Analyzer. The gas specificity is provided by the detector which is filled with CO gas. Pressure variations in the detector gas are caused by absorption of the chopped infrared beam at exactly those infrared wavelengths removed from the infrared beam by the unknown CO; the detector provides a sensitive measure of the unknown CO.

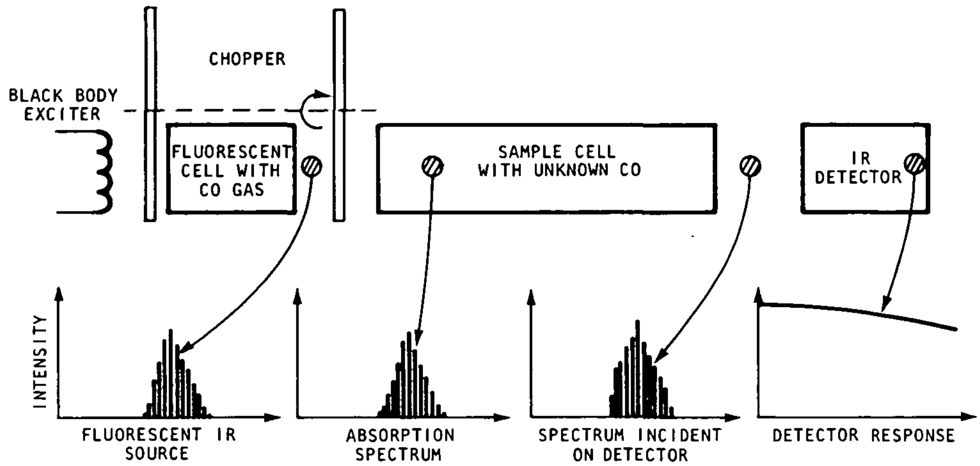



FIGURE 20. Simple Fluorescent NDIR CO Analyzer. The source emits a band of infrared lines which correspond exactly to the band of absorption lines of the CO sample. The problems described above of detector microphonics and sensitivity to $CO_2$ and $H_2O$ are eliminated.

ADDENDUM/ATTACHMENT 1

The fluorescent analyzer solves many of the problems of other NDIR analyzers by eliminating all unneeded infrared radiation from the infrared source and therefore from the analysis process. Unwanted interfering gases are not detected because the radiation needed to detect them is simply not there. The IR detector, typically solid state or pyroelectric, is free from the microphonic and stability problems of the gas-filled detector described above. The fluorescent cell is hermetically sealed and contains no moving parts or electrical connections.

## THE ARKON SCIENTIFIC LABS FLUORESCENT ISOTOPE CHOPPER NDIR ANALYZER

An advanced form of fluorescent NDIR analyzer is schematically shown in Figure 21. Two isotopes of CO are used in the analyzer. This removes the requirement of a separate standard cell and causes the analyzer to be independent of changes in instrumental parameters which plague present commercial analyzers.

As discussed in the figure caption, two stable isotopes of CO are used in the fluorescent cell, one common ($^{12}C^{16}O$, 100%) and one rare ($^{12}C^{16}O$, 0.2%). The fluorescent radiation of the rare $^{12}C^{18}O$ is slightly shifted in wavelength from that of $^{12}C^{16}O$ and is therefore not absorbed by $^{12}C^{16}O$. The $^{12}C^{18}O$ radiation is used as a standard radiation against which the $^{12}C^{16}O$ radiation, absorbed by the predominantly $^{12}C^{16}O$ gas sample, is compared. The output of the instrument is the ratio

$$\text{CO concentration} = \text{constant} \times \frac{^{12}C^{18}O - {}^{12}C^{16}O}{^{12}C^{18}O} \qquad (1)$$

This ratio is independent of most parameters of the instrument. If, for example, the output of the fluorescent cell were to unpredictably drop a factor of 10, the ratio (1) would remain constant and the instrument output would remain constant and accurate.

## SUMMARY

The main advantages of the Arkon analyzer over conventional analyzers are:

1. A fluorescent source which emits a few milliwatts of energy. The CO emission spectrum is strongly absorbed by atmospheric CO, yielding an instrument with improved sensitivity and accuracy at low concentrations. The specific source makes for very high rejection ratios of interfering gases.

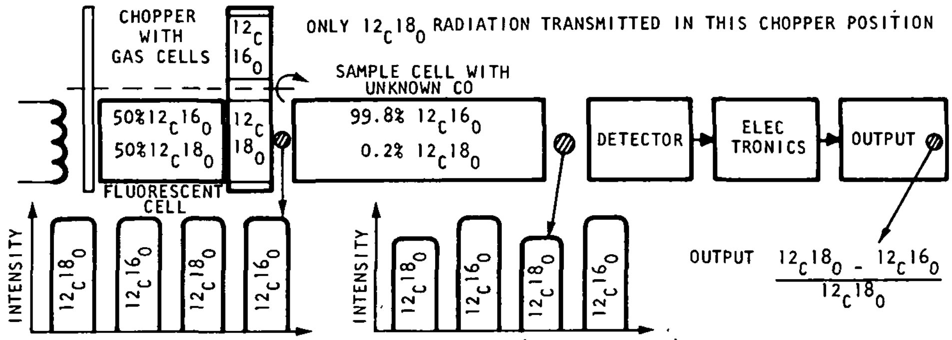



FIGURE 21. Isotopic Fluorescent NDIR CO Analyzers. $^{12}C^{18}O$ is a rare but stable isotopic form of $^{12}C^{16}O$; $^{12}C^{18}O$ radiation is not absorbed by $^{12}C^{16}O$. The chopper blade contains gas cells which chop the fluorescent beam into an alternating sequence of $^{12}C^{16}O$ and $^{12}C^{18}O$ beams. The $^{12}C^{16}O$ beam is compared.

2. The single tube carries both sample and reference signals, as opposed to the conventional system where the analyzer has a separate tube for each signal. Consequently contamination reduces both signals proportionately, and when this is combined with the automatic gain control the signals can be drastically reduced and the readings still remain unimpaired.

3. A semiconductor detector which is not subject to error due to shock and vibration.

4. No elaborate sample collecting apparatus is required due to immunity to water vapor and dirt. In extremely dirty environments a simple filter is all that is required.

5. Easy maintenance, due to few simple parts and modularized construction.

6. Small size and light weight.

ADDENDUM/ATTACHMENT 2

ACCEPTANCE TEST DATA

CARBON MONOXIDE ANALYZER

Model 204-023220  Serial No. 001

Contract NAS9-12066

ADDENDUM/ATTACHMENT 2

TEST PLAN

CARBON MONOXIDE ANALYZER, MODEL 204-023220

## 1.0 PURPOSE:

This document defines the performance acceptance test plan for CO monitors model 204, serial numbers 001 and 002, built under contract NAS9-12066. These instruments are preproduction prototypes, therefore, some of the span, temperature coefficient, and cross-sensitivity tests define the baseline performance of this type instrument. The abbreviated acceptance test may be applied to future production units.

## 2.0 REFERENCES:

2.1 Operating Manual Type 204 Carbon Monoxide Analyzer

## 3.0 EQUIPMENT:

3.1 CO Analyzer Model 204. This analyzer is to be tested for baseline and acceptance performance.

3.2 Environmental chamber Associated Testing Labs, Model SK-2105, or equivalent.

3.3 Zero and Calibration gases.

3.3.1 Zero-Gas, Dry $N_2$ < 1.0 ppm CO
3.3.2 Span Gas, 22 ppm CO $\pm 2\%$ analysis
3.3.3 Span Gas, 53 ppm CO $\pm 2\%$ analysis
3.3.4 Span Gas, 80 ppm CO $\pm 1\%$ analysis
3.3.5 Span Gas, 125 ppm CO $\pm 1\%$ analysis
3.3.6 Freon 12 2300 ppm, balance $N_2$, < 1 ppm CO
3.3.7 $N_2O$ 100 ppm balance $N_2$, < 1 ppm CO
3.3.8 $CO_2$
3.3.9 Propane

3.4 Two Strip-chart recorders.

## 4.0 REQUIREMENTS:

4.1 Range: 0-100 millitorr CO (132 ppm at 760 torr)

4.2 Detectable limit: 5% of full scale (5 millitorr)

4.3 Accuracy ±5% of full scale including errors resulting from span drift, short term zero drift, temperature, peak to peak noise and cross-sensitivity to the following levels of atmospheric contamination:

| Contaminant | Level |
|---|---|
| $N_2O$ | 100 ppm |
| $O_2$ | 25% |
| $H_2$ | 2% |
| $CO_2$ | 3% |
| FREON 11 | 1500 ppm |
| FREON 12 | 1500 ppm |
| FREON 114 | 1500 ppm |
| Hydrocarbons | 1% |
| $CH_4$ | 300 ppm |
| $H_2O$ | 3% |

4.4 Linearity. ±10% of reading from best fit straight line through the zero-zero coordinate point.

4.5 Pressure: 20 to 40 in. Hg.

4.6 Temperature: 50 to 115°F.

## 5.0 VERIFICATION PROCEDURE

5.1 Span and zero temperature coefficient.

5.1.1 With the span and zero compensation circuits inactive, set signal level to 5% of full scale with the zero trim control, record zero CO signal level and span signal level as a function of environmental chamber temperature.

5.1.1.1 Let the chamber stabilize at 50°F while flowing zero gas through the instrument at approximately 0.5 ℓ/min. Record signal level on a chart recorder.

5.1.1.2 When signal level has stabilized, (approximately 45 minutes) flow span gas (120 ppm $\pm$10 ppm $\pm$1% analytical accuracy) through the instrument at approximately 1 ℓ/min for 10 minutes. Then repeat with 50 ppm $\pm$10 ppm, 2% analytical accuracy.

5.1.1.3 Flow zero gas through instrument at approximately 1 ℓ/min for 10 minutes.

5.1.1.4 Actuate zero tube, with an externally connected switch for 5 minutes.

5.1.1.5 Increase chamber temperature by 10°F and repeat Steps 5.1.1.1 through 5.1.1.4 using 50 ppm span gas only until chamber temperature reaches 110°F. Reset the zero level at 5% of full scale and span with 120 ppm span gas.

5.2 Temperature compensation adjustments, span and zero.

5.2.1 At ambient temperature, make an initial setting of the zero temperature compensation trimmer based on the instruments basic zero temperature coefficient determined in Paragraph 5.1. The trimmer provides compensation of approximately 3 millitorr/°C plus (CCW) or minus (CW) full range.

5.2.2 Set the span temperature compensation trimmer, based on the coefficient determined in Paragraph 5.1.

5.2.3 With the chart recorder, record span (120 ppm) and zero (zero gas and internal zero) at 60°F and 100°F.

5.2.4 Adjust span and zero temperature compensation trimmers to trim out the difference between 60°F and 100°F readings. Repeat Paragraphs 5.2.4 and 5.2.5 until difference between 60°F and 100°F readings is $\leq$ 3% of full scale.

5.3 Pressure compensation adjustment, Span.

5.3.1 Introduce span gas at 20 and 40 inHg and note span with pressure signal input corresponding to 30 inHg (7.213 V) and adjust span compensation trimmer to give true span at high and low pressure with corresponding input signals (9.616 V) and (4.80 V). Span error should be $\leq$ 3% of full scale.

5.3.2 Set Zero Pressure compensation trimmer to null effect of the pressure compensation.

5.3.3 Verify span and zero at 20 and 40 inHg and repeat Paragraphs 5.3.1 and 5.3.2 as required to obtain span and pressure deviation of $\leq$ 3% of full scale.

## 6.0 ACCEPTANCE TEST

6.1 Zero

6.1.1 Turn instrument on, allow to warm up, and zero per model 204 instruction manual.

6.1.2 Verify zero tube actuation by flowing zero gas through the instrument (unless history of gas is known, it is likely that as much as 2 millitorr of CO will be present at zero-gas).

6.2 Span and cross-sensitivity

6.2.1 With instrument operating from previous test, flow calibration gases with 3 different known concentrations of CO (recommended 10 millitorr, 50 millitorr, 90 millitorr) and maximum concentrations of contaminant gases through the instrument. Allow 10 minutes per gas to insure that sample lines are free of the previous gas. This test is best conducted with a chart recorder monitoring instrument signal output. If a digital output is used, the readings should be averaged.

6.2.2 Reverify zero per Paragraph 6.1.2

6.3 Line Voltage

6.3.1 Repeat Paragraph 6.2 using the 80 millitor span gas at high and low voltage.

6.4 Temperature stability.

6.4.1 Repeat Paragraph 6.2 at 50°F and 110°F.

6.5 Acceptance Criteria

6.5.1 The performance should meet the requirements of Section 4.0.

## ~ SPAN - ZERO CALIBRATION DATA ~

| SPAN STIMULUS → | | 128 (1) PPM | | 106 (2) PPM | | 103 (2) PPM | | 85 (1) PPM | | [illegible] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TEMP | | 30" | 40" | 30" | 40" | 30" | 40" | 30" | 40" | 30" | 40" |
| 61° ~~50~~ °F | S/B | 97 | | | | | | | | | |
| | MEASURED | 96 | | | | | | | | | |
| 76°F ~~80~~ °F | S/B | 97 | | | | | | 64.4 | | 31.0 | |
| | MEASURED | 97 | | | | | | 65 | | 32.6 | |
| 96°F ~~110~~ °F | S/B | 97 (3) | — | 80.3 | — | 78.3 | — | 64.4 | 86.0 | | |
| | MEASURED | 96 | — | 84 | — | 82 | — | 65 | 86 | | |

## ~ LINE VOLTAGE DATA ~

| LINE VOLTAGE → | | 103.5V | | 115 V | | 127.5V | |
|---|---|---|---|---|---|---|---|
| SPAN STIMULUS → | | 1mt | 64mt | 1mt | 64mt | 1mt | 64mt |
| 50°F | S/B | | | | | | |
| | MEASURED | | | | | | |
| 80°F | S/B | | | | | | |
| | MEASURED | | | | | | |
| 110°F | S/B | | | | | | |
| | MEASURED. | | | | | | |

(1) P&P GAS ± 1%
(2) SCOTT GAS ± 1%
(3) SPAN REFERENCE

GAS ANALYZER
TEST DATA SHEET

Part No: 204-023221

Serial No: 001

Date: 3-18/19-7?

Test Conductor: RUNYAN

AMBIENT PRESSURE: 760 mm Hg

**ARKON** Scientific Labs

930 Dwight Way
Berkeley, Calif. 94710
(415) 849-1377

~ SPAN - ZERO CALIBRATION DATA ~

| SPAN STIMULUS → | | 23±2% PPM | | 15.9±2% PPM | | 8.26±?% PPM | | 1.5 ① PPM | | Z-TUBE | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TEMP | | 30" | 40" | 30" | 40" | 30" | 40" | 30" | 40" | 30" | 40" |
| 61° ~~50~~ °F | S/B | | | | | | | | | | |
| | MEASURED | | | | | | | | | | |
| 80 °F | S/B | 17.4 | | 12 | | 6.2 | | 1.0 | | 0.0 | |
| | MEASURED | 19.3 | | 12 | | 3.5 | | 1.4 | | 0 | |
| 96 ~~110~~ °F | S/B | 17.4 | — | | — | 6.2 | — | 1.0 ① | | | |
| | MEASURED | 20 | — | | — | 4 | — | 1.0 | | | |

~ LINE VOLTAGE DATA ~

| LINE VOLTAGE → | | 103.5V | | 115V | | 127.5V | |
|---|---|---|---|---|---|---|---|
| SPAN STIMULUS → | | 1mt | 64mt | 1mt | 64mt | 1mt | 64mt |
| 50°F | S/B | | | | | | |
| | MEASURED | | | | | | |
| 80°F | S/B | | | | | | |
| | MEASURED | | | | | | |
| 110°F | S/B | | | | | | |
| | MEASURED | | | | | | |

GAS ANALYZER
TEST DATA SHEET

Part No: 204-023221

Serial No: 001

Date: 3-18/19-72

Test Conductor: RUNYAN

AMBIENT PRESSURE:
760 mm Hg (30"H₂O)

① ZERO REFERENCE

ARKON Scientific Labs

930 Dwight Way
Berkeley, Calif. 94710
(415) 849-1377

~ SPAN - ZERO CALIBRATION DATA ~

| SPAN STIMULUS → | | 128 PPM | | 85 PPM | | 4 PPM | | 1.5 PPM | | Z-TUBE | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TEMP | | 30" | 40" | 30" | 40" | 30" | 40" | 30" | 40" | 30" | 40" |
| 58° ~~50~~ °F | S/B | | | 64.4 | | | | 1.0 | — | | — |
| | MEASURED | | | 66 | | | | 2.0 | — | | — |
| 80 °F | S/B | | | 64.4 | | | | | | | |
| | MEASURED | | | 66 | | | | | | | |
| 110 °F | S/B | | | 64.4 | 86.0 | | | 1.0mL.. | — | 1.0 | — |
| | MEASURED | | | 66 | 89.0 | | | 6 | — | 3 | — |

~ LINE VOLTAGE DATA ~

| LINE VOLTAGE → | | 103.5V | | 115V | | 127.5V | |
|---|---|---|---|---|---|---|---|
| SPAN STIMULUS → | | 1mt | 64mt | 1mt | 64mt | 1mt | 64mt |
| 50°F | S/B | / | / | / | 64.4 | / | / |
| | MEASURED | | | | 66 | | |
| 80°F | S/B | 1.0 | 64.4 | 1.0 | — | 1.0 | 64.4 |
| | MEASURED | 1 | 65 | 1 | — | 2.0 | 67 |
| 110°F | S/B | / | / | / | / | / | / |
| | MEASURED | | | | | | |

GAS ANALYZER
TEST DATA SHEET

Part No: 204-023??1

Serial No: 001

Date: 3-20-72

Test Conductor: WILLIAMS

AMBIENT PRESSURE 760mm Hg

ARKON Scientific Labs

930 Dwight Way
Berkeley, Calif. 94710
(415) 849-1377

## ~ SPAN - ZERO CALIBRATION DATA ~ 3%

| SPAN STIMULUS → / TEMP | | 100 PPM 30" | 40" | 2300 PPM 30" | 40" | 10% 30" | 40" | 7% 30" | 40" | 30" | 40" |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 °F | S/B | | | | | | | | | | |
| | MEASURED | | | | | | | | | | |
| 70° ~~80~~ °F | S/B | | | | | | | | | | |
| | MEASURED | | | | | | | | | | |
| 102°F ~~110~~ °F | S/B | 0 | | 0 | | 0 | | 0 | | 0 | |
| | MEASURED | 1 | | 1 | | -2 | | -1 | | -2 | |
| | | $N_2O$ | | FREON 12 | | PROPANE | | $CO_2$ | | $H_2O$ | |

## ~ LINE VOLTAGE DATA ~

| LINE VOLTAGE → | | 103.5V | | 115V | | 127.5V | |
|---|---|---|---|---|---|---|---|
| SPAN STIMULUS → | | 1mt | 64mt | 1mt | 64mt | 1mt | 64mt |
| 50°F | S/B | | | | | | |
| | MEASURED | | | | | | |
| 80°F | S/B | | | | | | |
| | MEASURED | | | | | | |
| 110°F | S/B | | | | | | |
| | MEASURED. | | | | | | |

GAS ANALYZER
TEST DATA SHEET

Part No: 204-023221

Serial No: 001

Date:

Test Conductor: WILLIAMS/RUNYAN

REJECTION / RATIO

Pambient = 760 mm Hg

**ARKON** Scientific Labs

930 Dwight Way
Berkeley, Calif. 94710
(415) 849-1377

~ SPAN - ZERO CALIBRATION DATA ~

| SPAN STIMULUS → | | 12.8 PPM | | 85 PPM | | PPM | | 1.5 PPM | | Z-TUBE | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TEMP | | 30" | 40" | 30" | 40" | 30" | 40" | 30" | 40" | 30" | 40" |
| 50 °F | S/B | | | | | | | | | | |
| | MEASURED | | | | | | | | | | |
| 80 °F | S/B | | | | | | | 1.0 | | | |
| | MEASURED | | | | | | | 1 | | | |
| 110 °F | S/B | | | 64.4 | 86.0 | | | 1.0 | | | |
| | MEASURED | | | 65 | 86 | | | -2 | | | |

~ LINE VOLTAGE DATA ~

| LINE VOLTAGE → | | 103.5V | | 115 V | | 127.5 V | |
|---|---|---|---|---|---|---|---|
| SPAN STIMULUS → | | 1mt | 64mt | 1mt | 64mt | 1mt | 64mt |
| 50°F | S/B | | | | | | |
| | MEASURED | | | | | | |
| 80°F | S/B | | | | | | |
| | MEASURED | | | | | | |
| 110°F | S/B | | | | | | |
| | MEASURED | | | | | | |

GAS ANALYZER
TEST DATA SHEET

Part No: 204-022221 *

Serial No: 001

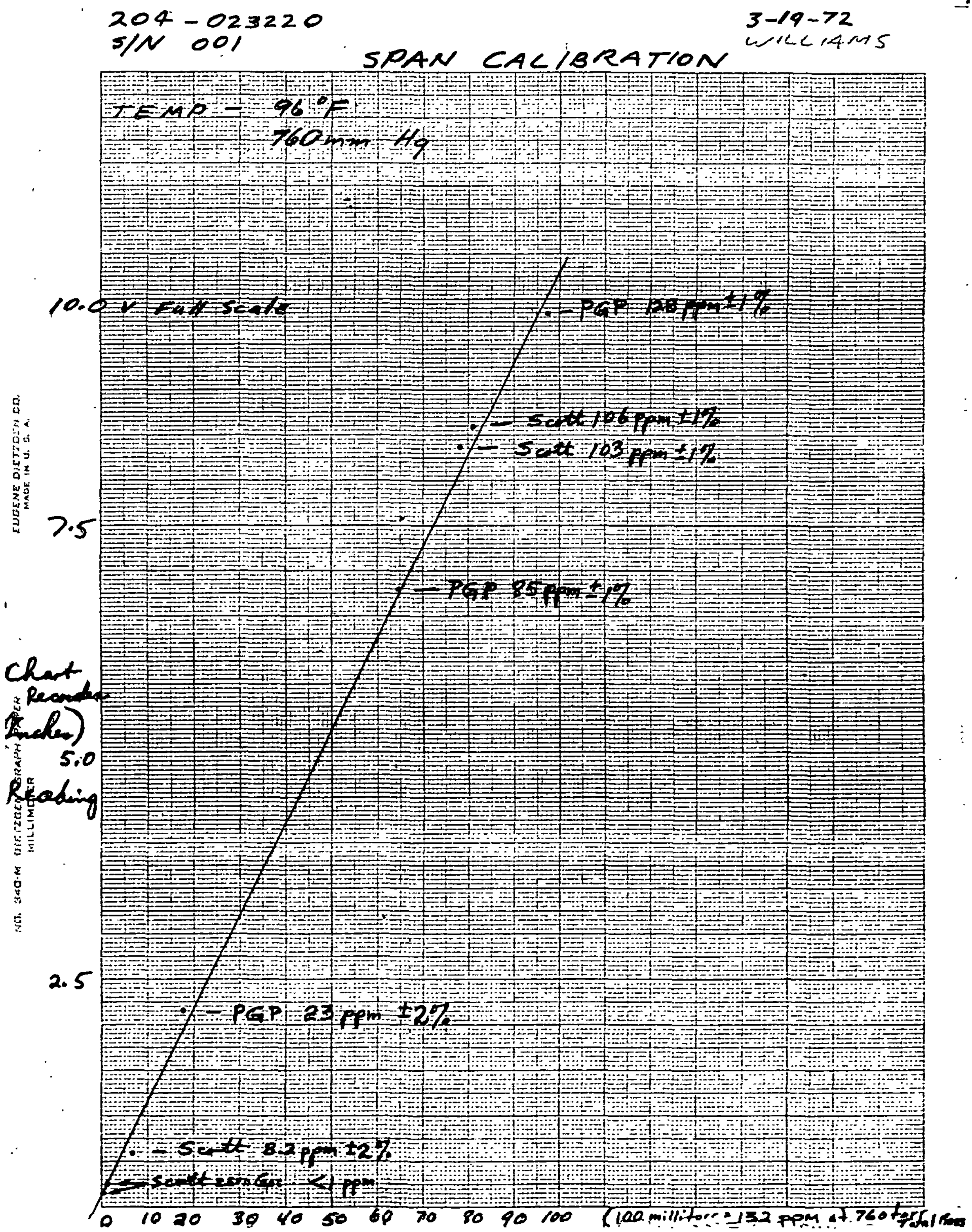
Date: 3-20-72

Test Conductor: WILLIAMS
PAMBIENT = 760 mm Hg

* SPARE COMPENSATION CARD

ARKON Scientific Labs

930 Dwight Way
Berkeley, Calif. 94710
(415) 849-1377

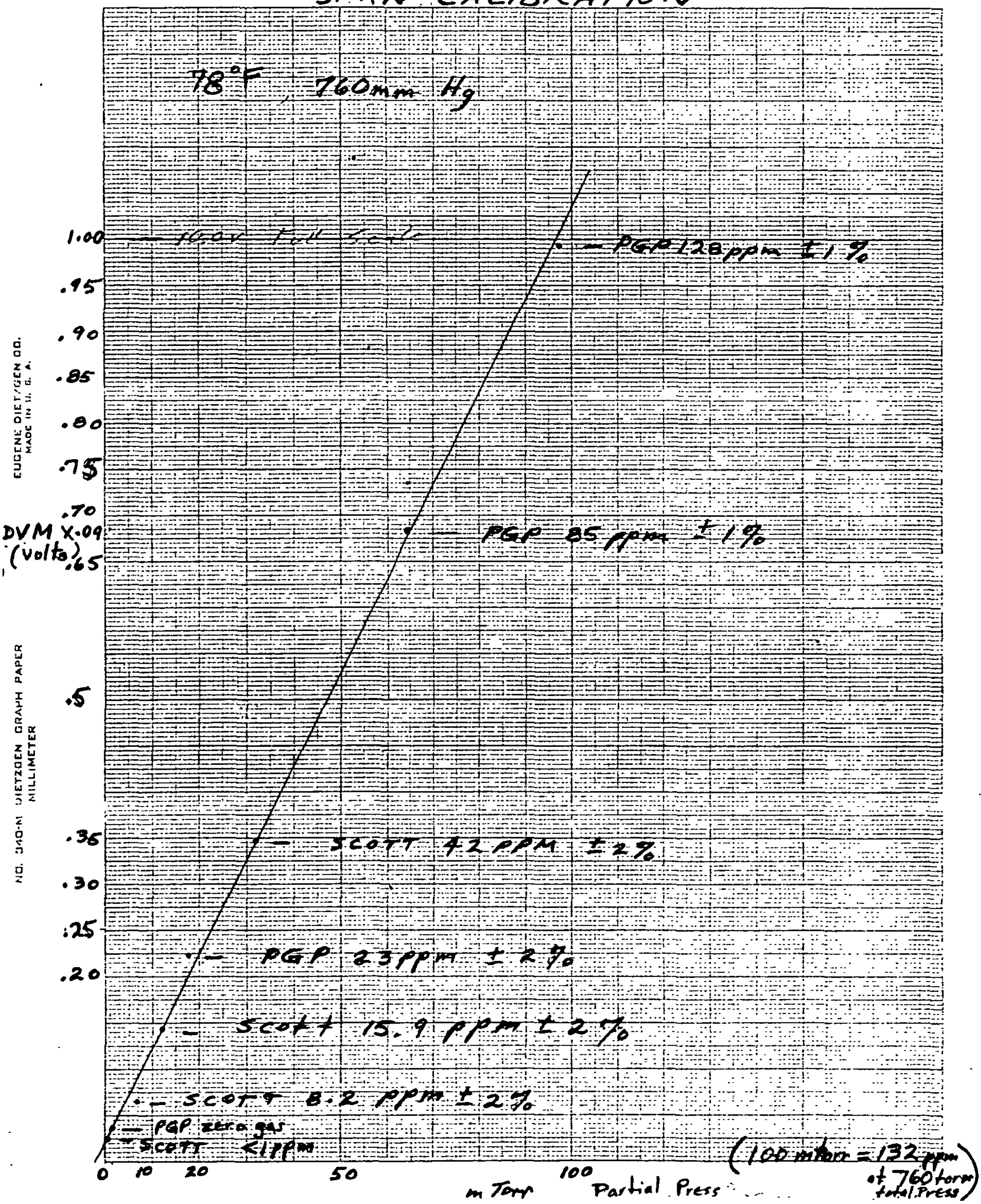


204 - 023220
S/N 001
3-19-72
WILLIAMS
SPAN CALIBRATION
TEMP — 96 °F
760mm Hg
10.0 V Full Scale
PGP 128 ppm ±1%
Scott 106 ppm ±1%
Scott 103 ppm ±1%
7.5
PGP 85 ppm ±1%
Chart Recorder (Inches) Reading
5.0
2.5
PGP 23 ppm ±2%
Scott 8.2 ppm ±2%
Scott zero Gas <1 ppm
0 10 20 30 40 50 60 70 80 90 100
(100 millitorr = 132 ppm at 760 torr Total Press
EUGENE DIETZGEN CO. MADE IN U.S.A.
NO. 340-M DIETZGEN GRAPH PAPER MILLIMETER

204-023220
S/N 001

3-19-72
WILLIAMS

SPAN CALIBRATION



THE PERKIN-ELMER CORPORATION

ENGINEERING NOTEBOOK

SUBJECT WORK ORDER NO.

24 March 74

CO Monitor ATP

.1 Zero

6.1.1 TIME ZERO check (Switch)

13:46 1.8 mT POT = [0485]

13:49 2.6 mT

13:53 4.8

13:55 sw out of zero check to allow sys add'l time to warm up

zero control was set at 4.85, CO reading was at 3.5
set zero control to 4.78. after two minutes CO reading was 3.5
set zero control to 4.7
After five minutes the reading was (1.4 - 2.0) average 1.7 mtorr

Switch in mix 5309

$P_{AMB}$ = 733 torr

| | |
|---|---|
| $CO_2$ | 2.03% |
| Ar | 1.02% |
| $H_2$ | 0.49% |
| $O_2$ | 22.1% |
| $N_2$ | Bal |

Wait six minutes. Reading is 00.0 mtorr

Mix 9406

$P_{amb}$ = 734 torr

| | | |
|---|---|---|
| CO | 9.4 ppm | 6.9 |
| F12 | 102 | |
| F114 | 105 | |
| Ar | 0.98% | |
| $CO_2$ | 1.00% | |
| $H_2$ | 1.52% | |
| $O_2$ | 18.13% | |
| $N_2$ | Bal | |

after six minutes the reading was 7.3 mtorr

ENTRY MADE BY ______ DATE ______

929 066 THE PERKIN-ELMER CORPORATION

ENGINEERING NOTEBOOK

ECT WORK ORDER NO.

24 MAR 72

ix 9377

| | | | |
|---|---|---|---|
| CO | 68 ppm | 49.8 | $P_{AMB}$ = 733 |
| F114 | 98 ppm | | |
| F12 | 99 ppm | | |
| $CO_2$ | 0.98% | | |
| Ar | 1.05% | | |
| $H_2$ | 1.42% | | |
| $O_2$ | 17.85% | | |
| $N_2$ | Bal | | |

+ six minutes. CO reads 60.0 mtorr

Mix 9401

| | | | |
|---|---|---|---|
| CO | 97 ppm | 71.1 | $P_{AMB}$ = 733 |
| F114 | 98 | | |
| F12 | 99 | | |
| $CO_2$ | 1.05% | | |
| Ar | 1.02% | | |
| $H_2$ | 1.48% | | |
| $O_2$ | 18.12% | | |
| $N_2$ | Bal | | |

WAITED IN EXCESS OF 6 MIN CO READS 85.2 ms

Depress self test Button ~ zero check mode

zero check = 00.0
Self Test # = "56.6" ~ 4 min

TRY MADE BY________________ DATE________

THE PERKIN-ELMER CORPORATION

ENGINEERING NOTEBOOK

2929 067

SUBJECT

WORK ORDER NO.

ACCEPTANCE TEST OF SPARE PW BOARDS

24 MAR '72

After warm-up. Zero check mode, monitor reads 1.9 avg.

Run CO free gas then - Mix 5309 after six minutes monitor reads 00.0

Mix #9406

after six minutes CO reads 9.3 mtorr

Mix #9377

after six minutes CO reads 62.3 mtorr

Mix #9401

after six minutes CO reads 85.8

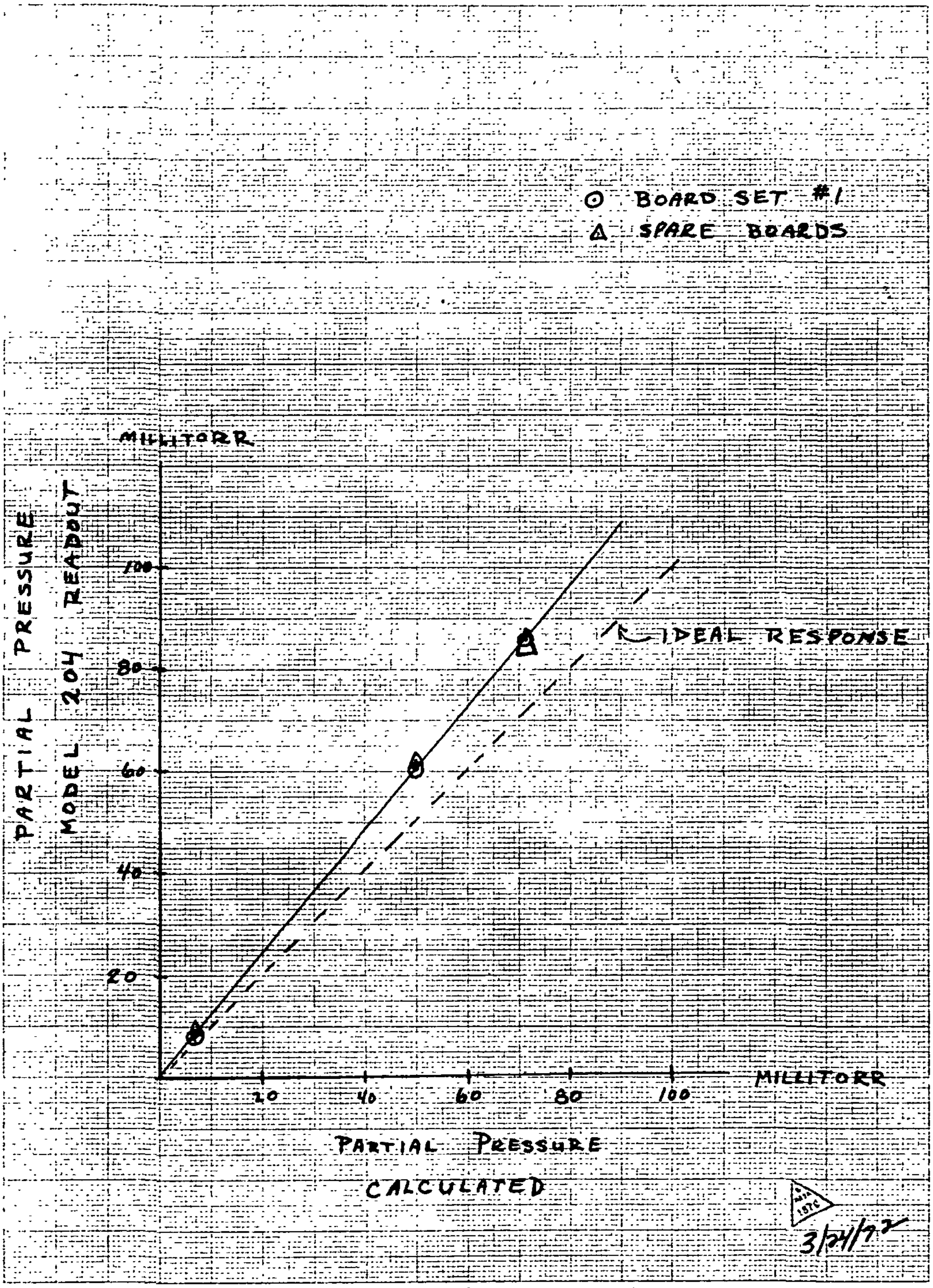
Zero check 1.1 avg

Self test 58.3 mtorr

ENTRY MADE BY

DATE

ADDENDUM/ATTACHMENT 2



ADDENDUM/ATTACHMENT 2

ACCEPTANCE TEST DATA

CARBON MONOXIDE ANALYZER

Model 204-023220 Serial No. 002

Contract NAS9-12066

GAS ANALYZER TEST DATA

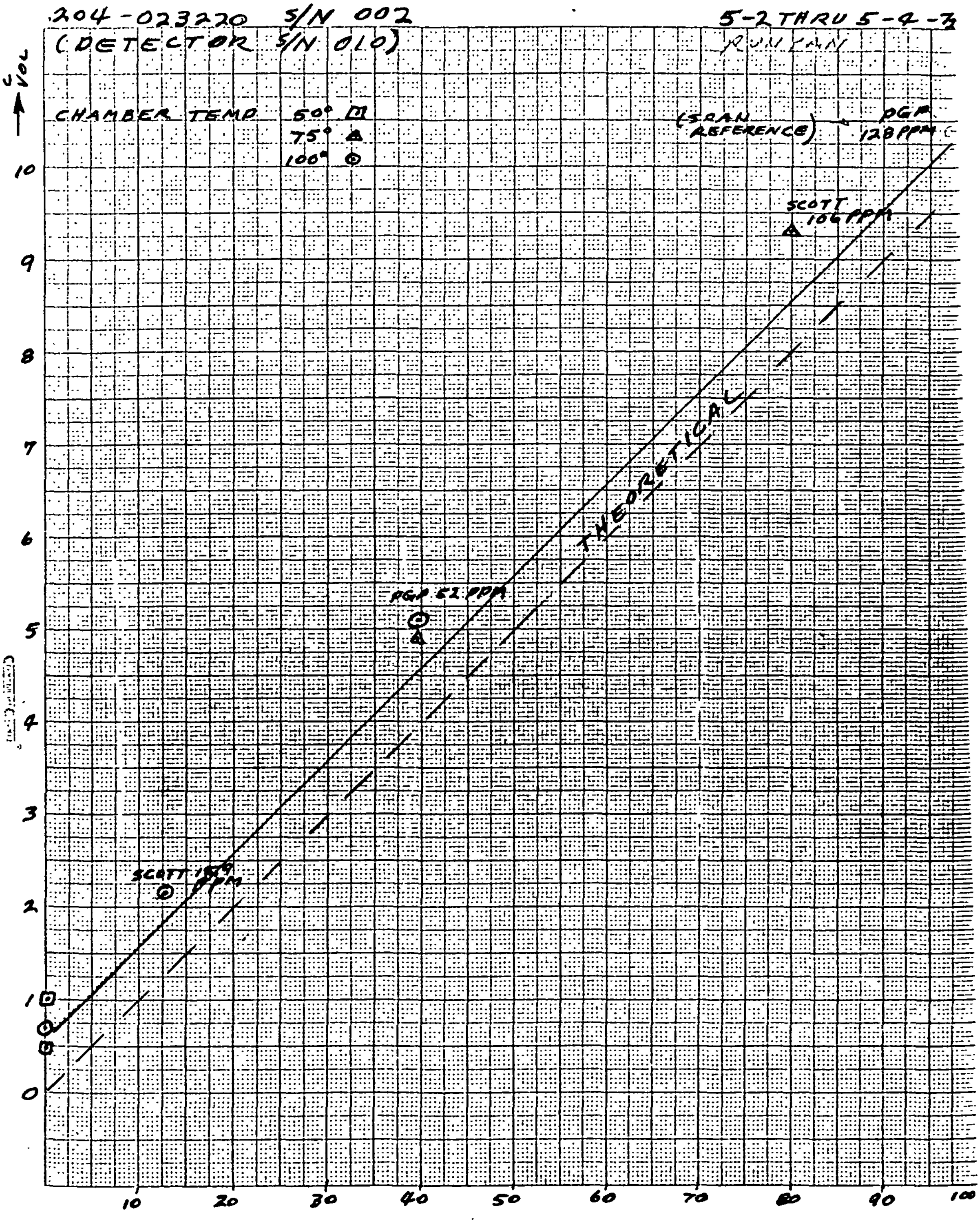
A R K O N SCIENTIFIC LABS

DETECTOR S/N 010

P/N 204-023220 S/N 002

Date 5-2-72 THRU 5-4-72 Test Conductor REDMOND/ P. NUNYAN

| Gas | PPM | Millitorr | Instrument Output Voltage | Zero Output Volts | Calculated Millitorr | Ambient Temp | Ambient Pressure | Line Voltage | Comments |
|---|---|---|---|---|---|---|---|---|---|
| PCP 13722 | 129 | 97 | 10.2 | .46 | 97 | 77° | 760 TORR | 120 | 5-2 6:20 PM |
| 13722 | 128 | 97 | 10.4 ✓ | .72 | 97 | 100°F | | " | 8:00 PM |
| SCRUBBED AMBIENT | | 0 | .6 | .6 | 0 | 50°F | | " | 11:00 PM |
| 13722 | 128 | 97 | 10.2 ✓ | .52 | 97 | 50°F | | " | 5-3 8:10 AM |
| Zero Tube | | 0 | .99 | .52 | 5 | 50°F | | " | 8:15 AM |
| SCRUBBED | | 0 | .54 | .54 | 0 | 50°F | | 127 | 10 AM |
| SCRUBBED | | 0 | .40 | .40 | 0 | | | 103 | NOISY SIGNAL 10:20 |
| SCRUBBED | | 0 | .64 | .64 | 0 | 100°F | | 120 | 1:30 PM |
| SCOTT A-5035 | 15.9 | 12.04 | 2.15 | .64 | 15.0 | 100°F | | " | 1:20 |
| FGP 30EC24 | 52.0 | 39.4 | 5.1 | .7 | 44.0 | 100°F | | " | 1:45 |
| 13722 | 128 | 97 | 10.5 | .8 | 97 | 100°F | | " | 1:50 |
| SCRUBBED | | 0 | .6 | .6 | 0 | 50°F | | " | 6 PM |
| SCRUBBED | | 0 | .55 | .56 ✓ | 0 | 75°F | | " | 10 PM |
| SCRUBBED | | 0 | .6 | .6 | 0 | 75°F | | " 5-4-72 | 3 AM |
| SCRUBBED | | 0 | .62 | .62 | 0 | 75° | | " | 8 AM |
| PCP 13722 | 128 | 97 | 10.4 | .62 | 93 | 75° | | " | 8:05 |
| SCOTT A-772C | 106 | 80.5 | 9.3 | .62 | 87 | 75° | | " | 8:10 |


204-023220 S/N 002
(DETECTOR S/N 010)
5-2 THRU 5-4-7?
CHAMBER TEMP 50° ▢
75° △
100° ⊙
(SPAN REFERENCE) PGP 128 PPM
SCOTT 106 PPM
PGP 52 PPM
SCOTT 15.9 PPM
THEORETICAL
% VOL
10
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
60
70
80
90
100

2/2

DETECTOR S/N 010

GAS ANALYZER TEST DATA

P/N 204-023220 S/N 002

A R K O N SCIENTIFIC LABS

Date 5-4-72 Test Conductor RUNYAN/ RECHMOND

| Gas | PPM | Millitorr | Instrument Output Voltage | Zero Output Volts | Calculated Millitorr | Ambient Temp | Ambient Pressure | Line Voltage | Comments |
|---|---|---|---|---|---|---|---|---|---|
| SELF-TEST | | — | 5.1 | 0 | | 77°F | 760 TORR | 117 | 10:30 AM |
| DCP 30524 | 52 | 39.4 | 4.21 | 0 | 42.1 | 77°F | " | " | 10:36 AM |
| | | | | | | | | | |
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ADDENDUM/ATTACHMENT 2

ENGINEERING NOTEBOOK

SUBJECT WORK ORDER NO.

8 May '72

Carbon Monoxide Monitor ATP
Model 204-025220 Serial # 02
Contract # NAS9-12066 (used in conjunction with ACS SN001)

1.0 to 5.0 ATP Documentation & Setup Information
6.0 Acceptance Test
6.1 Zero
6.1.1 - System turned on since 6 May PM & "zeroed" many times since
6.1.2 - Verify zero
16:02 switched to "zero" mode Pot = [0507]
16:09 CO output = 5.2 mT Return to "operate" mode
16:11 Admit "zero" gas - Prep $N_2$ Bottle # 6047 P
16:16 CO output = 4.8 mT

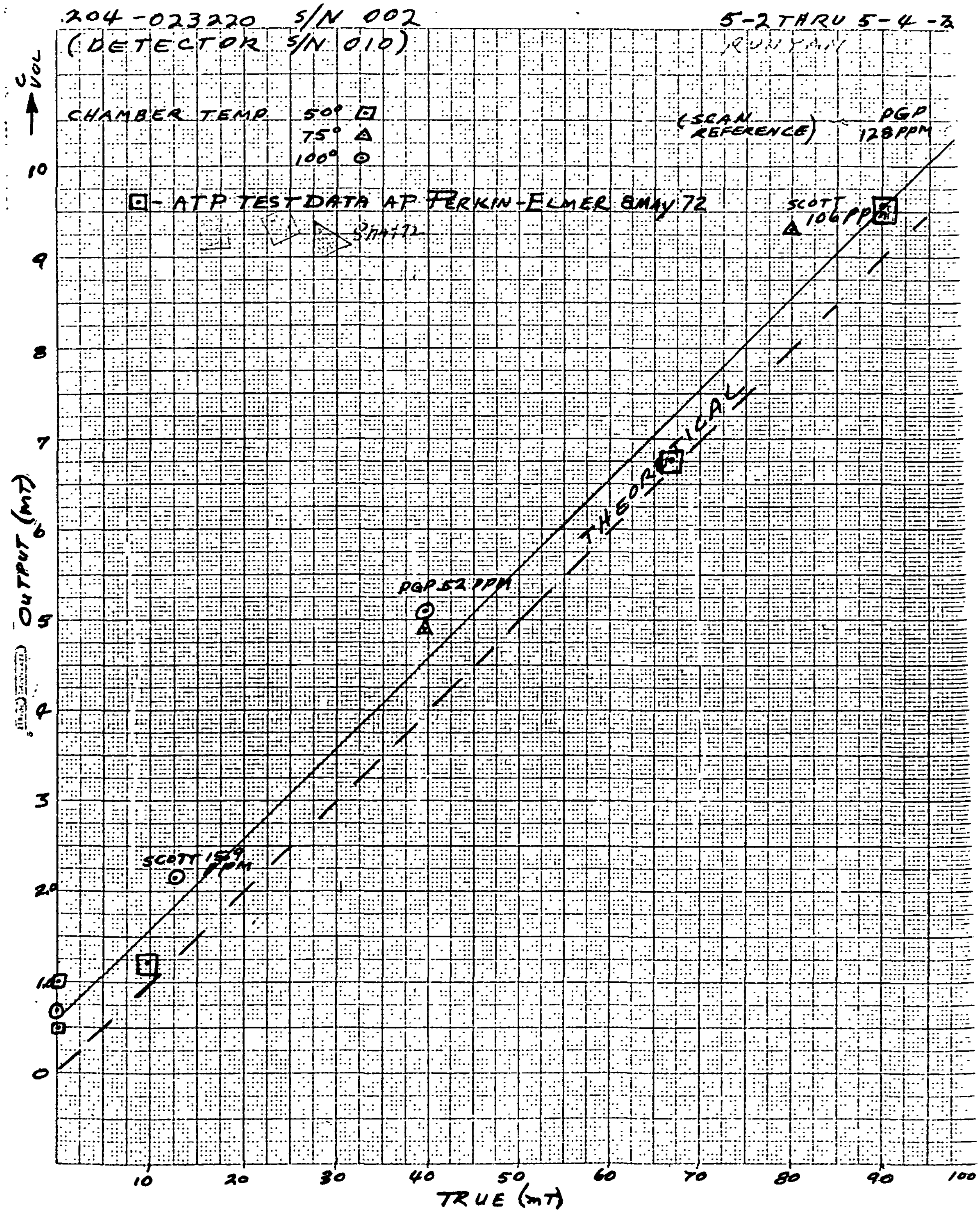
6.2 Span & Cross-Sensitivity
6.2.1
16:17 Admit mix # 9406 at 740T — 9.4 ppm CO + Mixture Bal.
16:22 CO output = 12.5 mT Calc CO = 6.96 mT
16:24 Admit mix # 9377 at 740T - 68 ppm CO + Mixture Bal
16:28 CO output = 67.7 mT Calc CO = 50.3 mT
16:30 Admit mix # 9401 at 740T 97 ppm CO + Mixture Bal
16:36 CO output = 95.1 mT Calc CO = 71.8 mT

6.2.2 Reverify zero w/ "zero" gas
16:36 Admit mix # 6047P - $N_2$ Prep at 740T
16:41 CO reads 6.8 mT Pot = [0507]

6.3 Line Voltage - Delete test
6.4 Temperature Stability - Delete test
6.5 Acceptance Criteria - Instrument meets requirements of Sec 4.0

8 May 72

ENTRY MADE BY Joseph H. Stead DATE 8 May 72
READ & UNDERSTOOD BY Verified [signature] DATE 5-8-72



204-023220 S/N 002
(DETECTOR S/N 010)
5-2 THRU 5-4-3
CHAMBER TEMP 50° □
75° △
100° ⊙
□ - ATP TEST DATA AT PERKIN-ELMER 8 MAY 72
(SCAN REFERENCE)
PGP 128 PPM
SCOTT 106 PPM
THEORETICAL
PGP 52 PPM
SCOTT 15.9 PPM
OUTPUT (mT)
TRUE (mT)
0
1.0
2.0
3
4
5
6
7
8
9
10
10
20
30
40
50
60
70
80
90
100

DETECTOR S/N 010

GAS ANALYZER TEST DATA

A R K O N SCIENTIFIC LABS

P/N 204-023220 S/N 002

Date 5-2-72 THRU 5-4-72 Test Conductor REDMOND/ P. MAYAN

| Gas | PPM | Millitorr | Instrument Output Voltage | Zero Output Volts | Calculated Millitorr | Ambient Temp | Ambient Pressure | Line Voltage | Comments |
|---|---|---|---|---|---|---|---|---|---|
| PCP 13722 | 128 | 97 | 10.2 | .46 | 97 | 77° | 760 TORR | 120 | 5-2 6:20 PM |
| 13722 | 128 | 97 | 10.4 ✓ | .72 | 97 | 100°F | | " | 8:40 PM |
| SCRUBBED AMBIENT | | 0 | .6 | .6 | 0 | 50°F | | " | 11:00 PM |
| 13722 | 128 | 97 | 10.2 ✓ | .52 | 97 | 50°F | | " | 5-3 8:10 AM |
| Zero Tube | | 0 | .99 | .52 | 5 | 50°F | | " | 8:15 AM |
| SCRUBBED | | 0 | .54 | .54 | 0 | 50°F | | 127 | 10 AM |
| SCRUBBED | | 0 | .40 | .40 | 0 | " | | 103 | NOISY SIGNAL 10:20 W/ [illegible] |
| SCRUBBED | | 0 | .64 | .64 | 0 | 100°F | | 120 | 1:30 PM |
| SCOTT A-5035 | 15.9 | 12.04 | 2.15 | .64 | 15.0 | 100°F | | " | 1:40 |
| FGP 30EC24 | 52.0 | 39.4 | 5.1 | .7 | 44.0 | 100°F | | " | 1:[illegible]5 |
| 13722 | 128 | 97 | 10.5 | .8 | 97 | 100°F | | " | 1:50 |
| SCRUBBED | | 0 | .6 | .6 | 0 | 50°F | | " | 6 PM |
| SCRUBBED | | 0 | .55 | .56 ✓ | 0 | 75°F | | " | 10 PM |
| SCRUBBED | | 0 | .6 | .6 | 0 | 75°F | | " | 5-4-72 3 AM |
| SCRUBBED | | 0 | .62 | .62 | 0 | 75° | | " | 8 AM |
| PCP 13722 | 128 | 97 | 10.4 | .62 | 98 | 75° | | " | 8:05 |
| SCOTT A-772C | 106 | 80.5 | 9.3 | .62 | 87 | 75° | | " | 8:10 |

2/2

GAS ANALYZER TEST DATA

A R K O N SCIENTIFIC LABS

DETECTOR S/N 010

P/N 204-023220 S/N 002

Date 5-4-72 Test Conductor RUNYAN/ REDMOND

| Gas | PPM | Millitorr | Instrument Output Voltage | Zero Output Volts | Calculated Millitorr | Ambient Temp | Ambient Pressure | Line Voltage | Comments |
|---|---|---|---|---|---|---|---|---|---|
| SELF-TEST | | — | 5.1 | 0 | | 77°F | 760 TORR | 117 | 10:30 AM |
| DCP 309224 | 5.2 | 39.4 | 4.21 | 0 | 42.1 | 77°F | " | " | 10:32 AM |
| | | | | | | | | | |
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ENGINEERING NOTEBOOK

SUBJECT — WORK ORDER NO.

8 MAY '72

CARBON MONOXIDE MONITOR ATP
MODEL 204-025220 SERIAL # 02
CONTRACT # NAS9-12066 (USED IN CONJUNCTION WITH ACS SN001)

1.0 TO 5.0 ATP DOCUMENTATION & SETUP INFORMATION
6.0 ACCEPTANCE TEST
6.1 ZERO
6.1.1 - SYSTEM TURNED ON SINCE 6 MAY PM & ZEROED MANY TIMES SINCE
6.1.2 - VERIFY ZERO
16:02 SWITCHED TO ZERO MODE POT = [0507]
16:09 CO OUTPUT = 5.2 mT RETURN TO "OPERATE" MODE
16:11 ADMIT "ZERO" GAS - PREP $N_2$ BOTTLE # 6047 P
16:16 CO OUTPUT = 4.8 mT

6.2 SPAN & CROSS-SENSITIVITY
6.2.1
16:17 ADMIT MIX #9406 @ 740T — 9.4 ppm CO + MIXTURE BAL.
16:22 CO OUTPUT = 12.5 mT CALC CO = 6.96 mT
16:24 ADMIT MIX # 9377 AT 740T — 68 ppm CO + MIXTURE BAL
16:28 CO OUTPUT = 67.7 mT CALC CO = 50.3 mT
16:30 ADMIT MIX # 9401 AT 740T 97 PPM CO + MIXTURE BAL
16:36 CO OUTPUT = 93.1 mT CALC CO = 71.8 mT

6.2.2 REVERIFY ZERO W/ "ZERO" GAS
16:36 ADMIT MIX # 6047P - $N_2$ PREP AT 740T
16:41 CO READS 6.8 mT POT = [0507]

6.3 LINE VOLTAGE - DELETE TEST
6.4 TEMPERATURE STABILITY - DELETE TEST
6.5 ACCEPTANCE CRITERIA - INSTRUMENT MEETS REQUIREMENTS OF SEC 4.0

8 MAY 72

ENTRY MADE BY Joseph H. Elwood DATE 8 May 72
READ & UNDERSTOOD BY VERIFIED [signature] DATE 5-8-72